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Fluoride in Groundwater and Dental Fluorosis in Rameswaram Area, Tamil Nadu, Southern India

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Abstract

The fluoride content in 419 groundwater samples from different sources in Rameswaram area, Southern India was determined in addition to the other physico-chemical parameters. From the results, it was evaluated that about 15% of the groundwater samples were found to contain the F content greater than the WHO recommended limit of 1.5 mg/l. The dental fluorosis survey among the school children also revealed that the percentage of boy victims was greater than the girl victims. The correlation values between Total Alkalinity (TA) and Fluoride (F) is evident for the leaching of Fluoride into the groundwater of the study area.

Keywords: Rameswaram; Fluoride; Groundwater; Dental fluorosis

Introduction

Fluoride in small amounts is an essential component for normal mineralization of bones and formation of dental enamel [1]. The main source of fluoride for human body is usually drinking water, covering about 75 – 90% of daily intake [2]. Fluoride concentration in groundwater depends on the pH, the intensity of the weathering process, and the amount of clay in the aquifer material [3,4]. The natural concentration of fluoride depends on the geological, chemical and physical characteristics of the aquifers [5]. Excessive fluoride intake causes fluorosis [6], cancer, arthritis and other diseases [7,8]. Around 200 million people from 25 nations have health risks because of high fluoride in groundwater [9]. In India, there has been an increase in the incidence of dental and skeletal fluorosis with about 62 million people at risk [10] due to high fluoride concentration in drinking water. Dental fluorosis is endemic in 14 states and 150,000 villages in India with the problem most pronounced in the states of Andhra Pradesh, Bihar, Gujarat, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu, and Uttar Pradesh [11]. Brouwer et al (1988)[12] stated that F^- is attracted by positively charged calcium ions, due to its strong electronegative charges, in teeth and bones and, therefore, excessive intake of fluoride causes pathological changes in teeth and bones.

In general, aridity of climate is one of the primary reasons for the origin of high fluoride in groundwater. Several processes, namely dissolution of fluoride bearing minerals, ion exchange and evaporative concentration can locally account for high fluoride concentration in groundwater [13-18].

Incidence of fluoride in groundwater is mainly a natural phenomenon, influenced by the local and regional geological setting and hydro geological conditions. The chief sources of fluoride in natural waters are fluoride-bearing minerals (fluorite, fluorapatite,cryolite and apophyllite) as well as F^- replacing OH^- in the ferromagnesium silicates (amphiboles and micas), and soil consisting of clay minerals [19-22]. The influence of local lithology, aided by other factors like semi-arid climate of the region may be responsible for higher concentration of fluoride in the groundwater of the region. Studies pertaining to fluoride concentration in groundwater have been conducted across India by various researchers [23 – 31]. The present contribution has been focused on the investigation of fluoride in groundwater of holy Rameswaram Island and dental fluorosis survey was conducted to make the people aware of the possible defluoridation techniques and consumption of drinking water with desirable fluoride content.

Materials and Methods

Details of the study area

As far as the Hindus are concerned, pilgrimage is an essential part of their life for worship of God by undertaking 'sthala yathra'. Rameswaram (Figure 1) is one of the pilgrimages, serving the purpose of promoting National Integration by attracting a vast confluence of people from Kashmir to Kanyakumari and from Bengal to Mumbai and also from abroad.

Geological set-up

The area under consideration is characterized with unconsolidated sediments of Quaternary age. The Archaeans are mainly represented by the Charnockites associated with quartzites, gneisses, garnetiferrous granulite and the Khondalites. In Rameswaram Island, the fluvio-marine deposits include detrital sand and dune sands. In places, the aeolian deposits comprise red sands; occur over a stretch of 8 km length with 3.2 km width, concordantly dispositional with sea coast. Often, these are separated by marshy black clay deposits. The sands are underlained by calcareous sandstones [32].

The marine formation comprises coastal plain deposits of sand and clay in varied proportion. Marine calcareous hardpan occurs as low terraces and platforms, with admixture of quartz, limonite and garnet concentrations. There are vast stretches of saline and alkaline soils found in the coastal blocks. Rameswaram Island contains mainly sandy soil and large quantities of limestone deposit. The potash content of soil is high in the entire coastal tract. Gypsum, limestone and magnesium compounds are noteworthy [32].

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Location and climate

The Ramanathapuram District is divided into two municipalities which further subdivides into 7 Taluks with 429 Panchayats which includes 400 revenue villages and 236 hamlet villages [33]. Rameswaram is located around an intersection of the 9°28'North Latitude and 79°3'East Longitude with an average elevation of 10 meters above the MSL, covering an area of 61.8 sq.kms and bearing a population of about 38,000, as on September 2007 [34]. This Indian Island having connection with main land assumes a shape of conch, is a Taluk with 1 Firka, 2 Revenue villages and 31 Hamlets. Climate prevails with a minimum temperature of 25°C in winter and a maximum of 36°C in summer. The average rainfall is 813mm.

Hydro-geological conditions

In most places groundwater available at a depth below 6 to 7 m

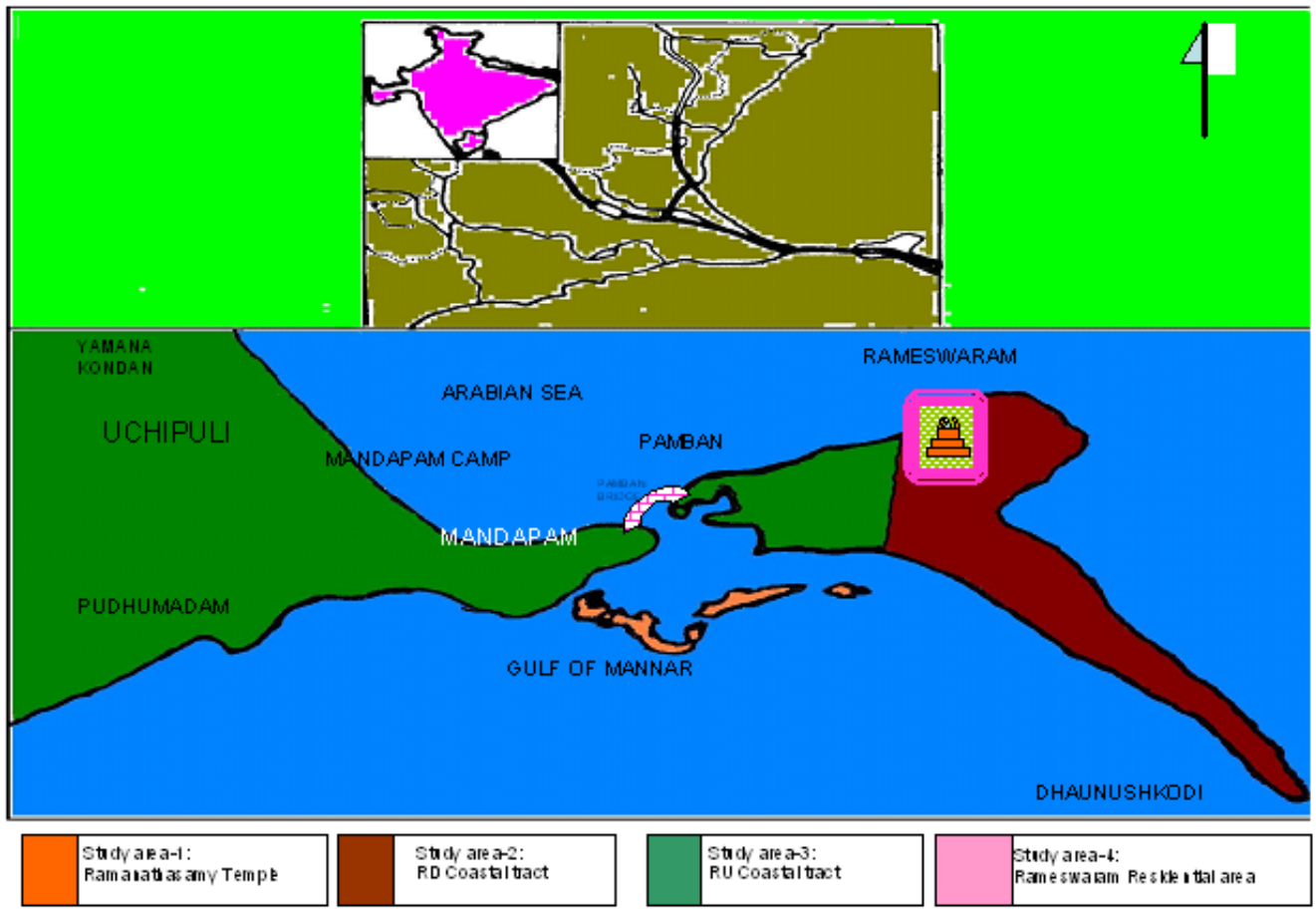

Figure 1: Map of the study area.

S. No	Location	No. of samples	Season	Minimum	Maximum	Mean	SD	No. of samples with Fluoride level (mg/l)		
								< 0.50	0.51 – 1.5	> 1.5
1.	Rameswaram temple	22	Summer	0.34	1.46	0.90	0.37	04	18	00
		22	Winter	0.06	1.56	0.87	0.37	03	17	02
2.	R – D tract	71	Summer	WDL	3.08	1.08	0.74	18	30	20
		40	Winter	WDL	1.92	0.45	0.55	26	12	02
3.	R – U Northern tract	61	Summer	WDL	2.96	1.23	0.65	07	39	15
		30	Winter	WDL	2.12	0.92	0.53	07	21	02
4.	R – U Southern tract	51	Summer	WDL	2.50	1.06	0.60	12	27	12
		35	Winter	WDL	2.02	0.79	0.56	12	20	03
5.	Residential area	50	SW	WDL	1.84	0.56	0.40	24	24	02
		21	NE	0.16	1.84	0.88	0.46	04	05	03
		16	NW	WDL	1.64	0.64	0.54	08	06	02
	Total	**419**						**125**	**231**	**63**

WDL – Within Detectable Level; SD – Standard Deviation

Table 1: Summary of Fluoride level in the groundwater samples of the study area.

is saline. If at all the fresh water available within 6 to 7 m depth dries up quickly subsequent to monsoon. Drinking water shortage is felt in most part of the year. The quality of groundwater varies from alkaline to high saline types in this study area. The saline aquifers in coastal tracts occur to a depth of 80 m below ground level followed by fresh water aquifers [32].

Agriculture and irrigation

The main stay is Paddy which accounts for 68%, followed by Chillies, Coconut, Groundnut etc. The water need is met mainly from tanks, tube wells and dug wells.

S. No	Rameswaram-Uchipuli Northern area	F (mg/l)	S. No	Rameswaram-Uchipuli Southern area	F (mg/l)
1	Mandapam camp – 1, well water	2.96	**34**	Nalupanai, well water	1.74
2	Mandapam camp – 2, well water	2.02	**35**	Natarajapuram, well water	1.56
3	Mandapam-pamban main road, well water	1.92	**36**	Natarajapuram, well water	2.30
4	Kathariya syrup factory, Uchipuli, well water	2.30	**37**	Ramakrishnapuram, well water	2.02
5	Panchayat board, pirappan valasai, well water	2.30	**38**	Mettu street, Thoppu, well water	1.64
6	Nadumanai kadu, well water	2.30	**39**	Fire station, well water	1.56
7	Panchayat union elementary School, Mandapam-Uchipuli road, well water	2.40	**40**	Mettu street, Villaiyutham thoppu, well water	1.84
8	Uchipuli, well water	2.50	**Rameswaram-Dhanushkodi tract (RD)**		
9	Pirappan valasai, well water	1.74	**41**	Ice factory, Verkodu, well water (10yrs old)	2.02
10	Pirappan valasai, pond water	1.74	**42**	Nethaji nagar, Verkodu-ww-(10 yrs old)	1.74
11	Uchipuli, well water (100 ft from seashore-6ft depth)	1.74	**43**	Railway station, Rmm, well water	1.92
12	Thillai Nachiyamman koil, mandapam-uchipuli road, well water	2.22	**44**	Marudhupandiyar nagar, Karaiyoor, well water (12ft)	3.08
13	Pirappan kanchi valasai, main road, well water (15 ft- 20 yrs)	2.78	**45**	Mariyamman nagar, Karaiyoor, well water	2.68
14	Pillai madam, Mandapam-Uchipuli road, well water	2.02	**46**	Karaiyoor,Rmm, well water	2.5
15	Corporation middle school, Uchipuli, well water (15 yrs-10 ft)	1.56	**47**	Nambunaiyaki amman koil street,Natarajapuram, well water	1.68
16	Aayeesha ice factory, Semmadam, well water	1.92	**48**	Fishermen colony, spring water	2.02
17	Annaisathya nagar, well water	1.84	**49**	Ramakrishnapuram, spring water	2.12
18	Fishermen colony, Gandhi Nagar,Mandapam, well water	1.74	**50**	Natarajapuram, spring water	2.12
19	Fishermen colony, Mandapam Camp, well water	2.12	**51**	Muthuramalinga thevar nagar, Verkodu, bore water	1.56
Rameswaram-Uchipuli Southern area			**52**	Marudhupandiyar nagar, Karaiyoor, Panchayat board water	2.60
20	Padhala kaliamman koil, mandapam-pamban road, well water	1.64	**53**	Natarajapuram, tank water	1.64
21	Mandapam - Uchipuli main road, well water	1.56	**54**	Sriram nagar, Verkodu, Panchayat board water	1.56
22	Level crossing, pudhumadam road, well water	2.12	**55**	Muthuramalinga thevar nagar,verkodu, bore water	1.92
23	Main road, mandapam, well water	1.84	**56**	Muthuramalinga thevar nagar,verkodu, well water	1.56
24	Kanchiappan valasai, Uandapam-Uchipuli main road, well water	1.74		**Residential area (South-West)**	
25	Pudhumadam road, well water	1.64	**57**	Melaradha veedhi, well water	1.84
26	Kanchiappan valasai, Mandapam-Uchipuli main road, well water	1.56	**58**	Market Street, well water	1.64
27	Maravar street, Mandapam, well water	1.74		**Residential area (North-West)**	
28	Pudhumadam road , well water	2.02	**59**	Melaradha veedhi, well water	1.64
29	Idayar valasai, well water	2.5	**60**	Market Street, well water	1.56
30	Govt. higher secondary school, Mandapam camp, well water	1.56	**61**	Melaradha veedhi, well water	1.84
31	Maraikayar pattinam(Kendhri Vidyalaya Higher Sec.School) , well water	2.05	**62**	Keelaradha veedhi, well water	1.64
32	Srivignesh guest house, MGS Nagar, well water	2.02	**63**	Keelaradha veedhi, well water	1.64
33	Kendri vidhyalaya matric school,Mandapam, well water	1.84			

Table 2: Fluorotic areas in Rameswaram Island of Tamil Nadu in India.

Parameters	Fluoride (F)										
	Holy aquifers		RD Coastal tract		RU Northern tract		RU Southern tract		Rameswaram Residential area		
	summer	winter	summer	winter	summer	winter	summer	winter	SW	NE	NW
pH	- 0.351	0.184	- 0.126	- 0.071	0.096	- 0.257	0.482	0.121	- 0.084	- 0.127	0.174
EC	- 0.478	0.430	0.035	0.108	0.125	0.128	0.304	0.301	- 0.038	0.201	0.141
TDS	0.533	0.427	0.039	0.106	0.121	0.133	0.296	0.248	- 0.038	0.203	0.144
Salinity	0.534	0.427	0.039	0.048	0.128	0.137	0.277	0.256	- 0.037	0.201	0.145
TA	0.284	0.004	0.061	0.093	0.480	0.569	0.529	0.053	0.020	0.026	0.008
CH	0.458	0.416	- 0.144	- 0.143	0.004	0.645	0.283	0.168	- 0.052	0.001	- 0.436
MH	- 0.134	0.295	- 0.010	0.228	- 0.140	0.172	- 0.042	0.119	- 0.042	0.345	0.504
Cl	0.502	0.438	0.117	- 0.111	0.178	0.042	0.262	- 0.108	- 0.060	0.040	0.015

EC – Electrical Conductivity; TDS – Total Dissolved Solids; TA – Total Alkalinity; CH – Calcium Hardness;
MH – Magnesium Hardness; Cl - Chloride

Table 3: Karl Pearson correlation values of F with the other water quality parameters.

School	Name of the School
1	St. Joseph's primary School, Verkottu St. Joseph's Higher Secondary School, Verkottu
2	Mandapam Panchayat Union Middle School, Natarajapuram
3	Mandapam Panchayat Union Middle School, Rameswaram (N-1)
4	Mandapam Panchayat Union Primary School, Ghandamadhana Parvadham
5	Dr. Abdul Kalam Nursery and Primary School, Pamban
6	Kendriya Vidyalaya Matriculation School, Mandapam Camp
7	Government Boys High School, Mandapam Camp Government Girls High School, Mandapam Camp
8	Manoharan Nursery and Primary School, Pamban
9	Government High School, Pamban
10	CSI Middle School, Pamban
11	Panchayat Union Elementary School, Pamban
12	Panchayat Union Elementary School, Mandapam

Table 4: List of Schools surveyed in the study area.

	% fluoride victims in the standard							
School	Gender	II	III	IV	V	VI	VII	VIII
1	Boys	0.0	**5.9**	8.8	**10.6**	**10.3**	8.0	6.3
	Girls	**3.2**	3.0	**11.7**	**10.1**	9.4	8.0	**7.4**
2	Boys	**23.5**	**5.6**	0.0	**4.8**	**20.0**	**16.1**	8.6
	Girls	17.9	2.3	0.0	0.0	8.1	10.8	**26.5**
3	Boys	**33.3**	0.0	0.0	10.5	31.6	0.0	0.0
	Girls	0.0	0.0	0.0	**20.0**	**35.3**	0.0	---
4	Boys	**20.0**	**33.3**	0.0	**50.0**	---	---	---
	Girls	0.0	**33.3**	0.0	0.0	---	---	---
5	Boys	**30.0**	0.0	---	---	---	---	---
	Girls	11.1	**8.3**	---	---	---	---	---
6	Boys	12.0	0.0	**23.8**	**12.5**	**13.3**	19.0	**9.0**
	Girls	**18.8**	**12.5**	6.7	2.2	0.0	**50.0**	6.7
7	Boys	---	---	---	---	**16.1**	6.5	**20.7**
	Girls	---	---	---	---	13.9	**9.4**	12.9
8	Boys	15.4	**30.0**	10.0	**36.4**	---	---	---
	Girls	**26.0**	0.0	**20.0**	33.3	---	---	---
9	Boys	---	---	---	---	**20.3**	10.6	**13.7**
	Girls	---	---	---	---	14.3	**20.0**	7.5
10	Boys	8.3	**20.0**	**13.8**	**22.2**	19.0	---	---
	Girls	**13.0**	15.0	10.3	21.7	**50.0**	---	---
11	Boys	**23.1**	**18.1**	15.4	5.3	---	---	---
	Girls	16.7	9.1	**23.1**	**8.0**	---	---	---
12	Boys	3.7	**20.7**	**19.8**	**20.7**	---	---	---
	Girls	**11.7**	11.1	14.6	7.7	---	---	---

Table 5: Fluorosis survey of children between 7 & 13 years in various schools of the study area.

Analysis and dental fluorosis survey

A total of 419 samples from bore well, open well, pond, spring and tank sources in the Rameswaram area (Table.1) located in Tamil Nadu State was collected and analyzed for Fluoride and other physico-chemical parameters *viz*., pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Salinity, Total Alkalinity (TA), Calcium Hardness (CH), Magnesium Hardness (MH), Total Hardness (TH) and Chloride. For Fluoride, the standard SPADNS (Sodium-2-(parasulphophenylazo)-1,8-dihydroxy-3,6-napthalenedisulphonate) method using a Spectrophotometer (Systronics Model – 106) was adopted and the other water quality parameters were analyzed as per the standard procedures [35].

The dental fluorosis survey in 12 schools was carried out for a total of 4755 students which includes 2519 boys and 2236 girls of age between 7 and 13years. The survey conducted among the School children was accompanied by a dentist to ensure the dental fluorosis victims.

Results and Discussion

The Fluoride content in the groundwater samples in various locations of the study area has been shown in Table 2. From the results, about 30% of the groundwater samples were registered less than 0.5 mg/l of F, 55% in the range of 0.5 to 1.5 mg/l of F and 15% of the samples have exceeded the tolerable F limit of 1.5 mg/l. The groundwater samples exceeding 1.5 mg/l of F along the Rameswaram-Dhanushkodi (RD) coastal tract were recorded with 28.2% in summer. The Northern and Southern sides of Rameswaram-Uchipuli (RU) coastal tract in summer accounted for 24.5% and 23.5% of aquifers having F content greater than 1.5 mg/l respectively. Oruc and Sansarci (1983)[36] suggested the dilution of groundwater sample containing high fluoride content with the sample containing low fluoride content is to prevent the dental fluorosis, while supplying enough fluoride for the protection against caries. The distribution of fluoride content in the groundwater samples that exceeded the recommended limit (WHO: 1.5 mg/l) has been given in Table 2. A well water sample at Marudhupandiyar Nagar in Karaiyoor was recorded with 3.08 mg/l and the ground water samples at Mariamman Nagar in Karaiyoor (well), Pirappan valasai (well) and Mandapam camp -1 (well) were registered with 2.68 mg/l, 2.78 mg/l and 2.96 mg/l respectively. The drinking water supplied to the local residents from Panchayat Board at Marudhpandiyar Nagar in Karaiyoor was found with 2.60 mg/l of Fluoride. Out of 63 groundwater samples, the Fluoride content in 21 samples was in the range of 2.0 to 2.5 mg/l and in 37 samples, it was in the range of 1.5-2.0 mg/l. The abundance of limestone can cause

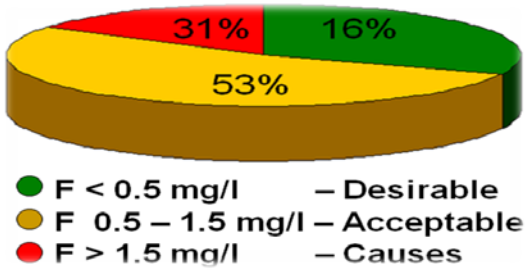

Figure 2: Percentage analysis of dental fluorosis victims among children of age between 7 and 13 years in Rameswaram Island.

Figure 3: A boy dental fluorosis victim in the study area.

fluoride dissolution in groundwater [37], which may also be a fact attributed to the fluoride pockets [38, 39] in the study area. The fluoride level of the groundwater samples in summer was found to be greater than in winter. The reason may be associated due to rainfall during winter which causes dilution of these aquifers. It was also reported [40] that a high concentration of fluoride in the coastal aquifers is indicative of the mixing of intrusive water with fresh water whereas the low level of fluoride may be attributed to the loss of fluoride in the form of aerosols to the atmosphere, by precipitation as insoluble fluorides, and by incorporation in the carbonate- or phosphate-containing tissues of living organisms [41]

The Karl Pearson correlation coefficients between Fluoride and other water quality parameters are given in Table 3. A positive correlation between fluoride and TA indicates the alkaline nature of groundwater, which promotes the leaching of fluoride and thus increasing the fluoride concentration in groundwater [4,42]. As HCO_3^- ion is the dominant species of carbon in the intermediate pH of water, a positive correlation is also observed between F^- and HCO_3^-. The positive relation between F^- and HCO_3^- can be explained by considering the mass law equation relating to calcite and fluorite when both are in contact with water [43, 44].

$$CaF_2(s) + HCO_3^- \rightarrow CaCO_3(s) + H^+ + F^-$$

$$K = [(a_{H+})(a_{F-})_2/[a_{HCO3}]$$

where, K is an equilibrium constant and "a" is the activity. Thus, at constant pH, any increase or decrease innbicarbonate concentration is accompanied by corresponding changes in fluoride concentration. In agreement with the earlier reports [45], a poor correlation between F and CH infers that the groundwater with high fluoride content is having low Ca^{2+} concentration. From the above observation it is clear that the concentration of fluoride in groundwater increases as the carbonate and bicarbonate content of water increases, and it decreases along with an increase in calcium and magnesium contents. Such an observation was also made by Ramamohana Rao et al. (1993) [46].

Based on the fluoride content of water samples, the fluoride endemic locations in the study area were identified. A survey in various schools was conducted among the school children for physical verification of dental fluorosis. The survey includes a total of 4755 students with 2519 boys and 2236 girls, between the age of 7 and 13 years (Table 4 and Table 5). The percentage of dental fluorosis victims has been shown in Figure 2 and a boy victim is shown in Figure 3.

In the standards V (School-4), VI (School-6) and VII (School-10) about 50% of dental fluorosis victims were identified. About 30% or more students were affected in the Schools 3, 4, 5 and 8. The overall survey revealed that the percentage of boy victims (12.4%) was greater than that of girl victims (10.9%). This is in agreement with a report by Ibrahein et al (1995) [47] which indicated that, more fluoride concentration in the teeth enamel of male children was observed than that of the female children. The groundwater samples with high F content need an immediate attention for the removal of fluoride by defluoridation techniques and the people along this coastal area need to be educated by awareness programs for fluoride and its impacts.

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